PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference JA/G20618WO	FOR FURTHER ACTION	See Form PCT/IPEA/416
International application No. PCT/GB2004/002483	International filing date *(day/month/year)* 15.06.2004	Priority date *(day/month/year)* 17.06.2003
International Patent Classification (IPC) or national classification and IPC F01C3/02, F01C21/16, F01C1/08		
Applicant SEE, Richard		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 12 sheets, as follows:
      - ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
11.01.2005	26.09.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Lequeux, F Telephone No. +31 70 340-4664

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/002483

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

2, 3, 9-20, 22, 23	as originally filed
1, 4-8, 21, 24	received on 06.05.2005 with letter of 03.05.2005

Claims, Numbers

21	received on 11.01.2005 with letter of 16.11.2004
1-20	received on 06.05.2005 with letter of 03.05.2005

Drawings, Sheets

1/24-24/24	as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☒ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☒ the claims, Nos. 21
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/002483

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-20
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-20
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-20
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:
D5: GB653185

The document D5 is regarded as being the closest prior art to the subject-matter of claim 1 and shows (the references in parentheses applying to this document) a rotary engine with a first rotation member (Fig 14, ref 11) and two second rotation members (17,17d).

The subject-matter of claim 1 differs from this known engine in that the rotation members do not have the particular cooperating profiles and associated cross-sections according to the features of claim 1 so that the complete compression, combustion, expansion cycle would take place in a working portion defined by the same two adjacent rotation elements.

The subject-matter of claim 1 is therefore new (Article 33(2) PCT).

The problem to be solved by the present invention may be regarded as to improve the recovery of power through an extended expansion of the gas in the engine while at the same time improving the sealing effect between the rotation members.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) as these features in combination are not known nor rendered obvious from the known state of the art. Hence the subject-matter of claim 1 is inventive.

The subject-matter of claim 1 is industrially applicable (Art 33(4) PCT).

Claims 2-20 are dependent on claim 1 and as such also meet the requirements of the PCT with respect to novelty, inventive step and industrial application..

06-05-2005
10/561369
GB0402483
IAP9 Rec'd PCT/PTO 14 DEC 2005

ROTARY ENGINE

This invention relates to rotary engines

EPO -DG 1
06. 05. 2005
116

The compression or expansion of gases occurs in a large variety of devices. Well known examples include pumps, compressors, blowers, exhausters, and rotary and hydraulic engines, all of which include some form of apparatus used to compress or expand gases.

As mentioned above, compressors are well known devices. One type of compressor is the reciprocating compressor. Reciprocating compressors have the advantage that they are able to operate at high pressures. However, reciprocating compressors have a large number of moving parts and are therefore relatively complex devices. One other type of compressor, the Roots compressor, has rotary instead of reciprocating motion and its resulting simplicity means that it has few moving parts and is reliable. Nevertheless, this type of compressor has its disadvantages. One such disadvantage is that it relies on "back-compression" to raise the pressure of the pumped gases. This means that no compression is performed on the low pressure input gases until they come into contact and mix with the higher pressure gases within the compressor. This irreversible process is inefficient, and leads to a higher drive power requirement and elevated air outlet temperatures.

Another type of rotary compressor, the Lysholm compressor, employs internal compression to overcome the problems caused by "back compression". Typically, these compressors are significantly more efficient. However, their performance depends in large measure upon maintaining very small clearances between the moving elements, thus presenting considerable manufacturing problems. Imperfect sealing between the elements leads to

According to an aspect of the present invention, there is provided a rotary engine for use with compressible fluids, the engine comprising: a first rotation element mounted to rotate about a first axis; a casing having a surface enclosing at least a part of the first rotation element, an elongate cavity of varying cross sectional area being defined between a surface of the first rotation element and the casing surface; and a plurality of second rotation elements mounted to rotate about respective different second axes, each second rotation element being mounted to project through a slot in the casing surface and to cooperate with the first rotation element surface so as to divide the cavity into adjacent working portions, wherein each second rotation element comprises a plurality of projecting portions having respective different radii about the second axis, the different radii causing the projecting portions to project into the cavity by respective different amounts, so that the volumes of the working portions vary as the first and second rotation elements rotate, wherein, in use, fluids in a working portion undergo compression, combustion and expansion as a closed volume, the closed volume being defined during the compression, combustion and expansion by the same two adjacent second rotation elements.

The first rotation element and each of the second rotation elements have a variable radius. The casing surface, which has a constant radius, and the first rotation element surface therefore define a cavity that extends around the first axis. As the first rotation element rotates about the first axis, the cavity also rotates about the first axis. Each of the second rotation elements project through the casing surface. As each of the second rotation elements rotate, the amount by which they project through the casing surface varies. In fact, rotation of the first rotation element and each of the second rotation elements is co-ordinated so that they mesh together to provide a seal. Each of the second rotation elements thus define a number of working portions of the cavity. Working portions may also be defined by the first rotation element where its radius is at a maximum by providing a seal with the casing. As the cavity rotates about the first axis, the volumes of the working portions of the cavity change, thus providing compression or expansion of a fluid within.

A rotary engine can thus be realised having a number of desirable qualities while at the same time being simple to manufacture and use. The rotary engine relies on internal compression thus avoiding the disadvantages associated with 'back compression', such as inefficiency. At the same time, the simplicity of the design allows effective sealing between the various elements of the rotary engine thus avoiding the manufacturing complexity and other problems associated with known internal compression rotary engines.

Preferably, the first and second rotation elements each comprise a plurality of integral segments each having different radii. For the second rotation elements, these segments are the projecting portions.

Preferably, the second rotation elements are distributed around the casing surface, each second rotation element being mounted to rotate about a respective axis that is perpendicular to both the first axis and the radius of the casing surface. In this way, a number of working portions of the cavity can be defined, and a compression and/or expansion process can be performed simultaneously in each.

The first rotation element may be internal to the casing surface with the plurality of second rotation elements being external to the casing surface. In this case, the first rotation element will be substantially cylindrical. Alternatively, the first rotation element may be external to the casing surface with the plurality of second rotation elements being internal to the casing surface. In this case, the first rotation element will substantially take the form of an annulus.

The rotary engine performs compression followed by expansion. Rotation of the first rotation element and each of the plurality of second rotation elements causes the volume of the working portions of the cavity to reduce and then increase during each cycle. Since compression and expansion are performed by different portions of the first rotation element surface, an engine having different compression and expansion ratios can be realised.

Preferably, the rotary engine also comprises ignition means for ignition of a compressed fluid prior to expansion. For example, the ignition means may comprise a spark plug. In this way, when gases within a working portion of the cavity are at a maximum pressure, a sudden further increase in pressure may be induced. For example, if the gases are a fuel and oxygen mix, a spark plug may induce combustion, as in a conventional petrol engine. Alternatively, if the gases include highly pressurised oxygen, the injection of fuel itself may induce combustion, as in a conventional diesel engine. Other means of causing a sudden further increase in pressure may be used, such as the injection of a small volume of high pressure, low temperature gas. The sudden increase in pressure allows more work to be extracted during expansion than was used in compression, thus powering the engine.

Preferably, the first rotation element also comprises at least one passage for fluid inlet or fluid outlet. The first rotation element may even comprise passages for both fluid inlet and fluid outlet. In this way, fluids can be drawn or forced into the working portions of the cavity, or exhausted or released from the working portions of the cavity.

The casing may also comprise at least one side valve, each of the at least one side valves being operative as a fluid inlet or fluid outlet only when adjacent to a working portion of the cavity, each of the at least one side valves being adjacent to a working portion of the cavity for a fraction of a cycle of the device. The rotary engine may therefore be designed so that the area of the casing

containing a side valve only forms a boundary of a working portion of the cavity when fluid inlet or fluid outlet is desired.

Preferably, each of the at least one side valves is operative to vary the flow rate of a fluid into a working portion of the cavity, to vary the pressure of fluid within a working portion of the cavity, or to vary a compression or expansion ratio of the rotary engine. Side valves may therefore provide a way of controlling the operation of the rotary engine.

Preferably, closed loop feedback control is used to control the operation of each of the at least one side valves, the closed loop feedback control being based on an operating parameter such as fluid inlet pressure, fluid outlet pressure and rotary speed. In this way, a number of parameters may be maintained in a steady state.

This invention also provides a rotary engine comprising two of the rotary devices described above. In this way, the respective second rotation elements may be arranged so that the net forces on the first rotation element are minimised. For example, this could be achieved by providing a second rotation element from each of the rotary engines on opposite sides of the integral first rotation element.

The invention will now be described by way of example with reference to the following figures in which:

Figures 1 and 2 show cross sections of a first rotary engine according to the invention in first and second positions respectively;
Figure 3 shows a side profile of a second rotation element of the first rotary engine according to the invention;
Figures 4 and 5 show cross sections of the first rotary engine according to the invention in third and fourth positions;
Figure 6 shows a cross section of a second rotary engine according to the invention;

Figure 7 shows a cross section of a third rotary engine according to the invention;

Figures 8 and 9 show cross sections of a fourth rotary engine according to the invention;

Figures 10 to 14 show cross sections of a fifth rotary engine according to the invention in first to fifth positions respectively;

Figures 15 and 16 show the surface of the first rotation element of the fifth rotary engine according to the invention in sixth and seventh positions respectively;

Figure 17 shows the surface of the first rotation element of a sixth rotary engine according to the invention;

Figure 18 shows a cross section of a seventh rotary engine according to the invention;

Figures 19 shows a cross section of an eighth rotary engine according to the invention;

Figures 20 to 27 show cross sections of the eighth rotary engine according to the invention in first to eighth positions respectively;

Figure 28 and 29 show cross sections of a ninth rotary engine according to the invention in first and second positions respectively;

Figure 30 shows the surface of the first rotation element of the ninth rotary engine according to the invention;

Figure 31 shows a cross section of a first compressor;

Figures 32 and 33 show the surface of the first rotation element of the first compressor in first to third positions respectively;

Figure 34 shows the surface of the first rotation element of a second compressor;

Figure 35 shows a cross section of a third compressor;

Figure 36 shows the surface of the first rotation element of the third compressor;

Figure 37 shows a cross section of a tenth rotary engine according to the invention;

Figures 31 to 33 show a first compressor. The first compressor operates in a similar way to the rotary engines according to the invention described above. However, the elimination of combustion and expansion stages from the operating cycle allows simplification. The compressor comprises a single second rotation element 3 that rotates at half the angular velocity of the first rotation element 1. Gases are drawn into the compressor, compressed and then released through a sliding valve 10. The sliding valve 10 can be used to control the extent to which the gases are compressed by the compressor. The first rotation element 1 may be designed so that, during release of the compressed gases, gases may flow between working portions of the cavity defined on opposite sides of the second rotation element 3. This provides an exit route for the gases as the working portion of the cavity contracts.

The compressor may comprise two second rotation elements in order to balance the forces on the first rotation element 1. This may be achieved using the techniques disclosed in figures 17 and 18 and the descriptions thereof.

Figure 34 shows a second compressor. In this compressor, the volume of the working portion of the cavity is larger than in the first compressor.

Figures 35 and 36 show a third compressor. In this compressor, sliding valves 10 are used to control the intake of gases rather than their expulsion.

The first, second, and third compressors may operate as expanders. In this case, compressed gases are fed into the fluid outlet and the first and second rotation elements are driven in the opposite directions to those shown in the figures.

Figure 37 shows a cross section of a tenth rotary engine according to the invention. In the tenth rotary engine, a number of small teeth 12 have been added to the second rotation elements 3. In this way, the first rotation element

Figures 42 to 46 illustrate some of the characteristics of the device according to the invention that distinguish it from known rotary devices. It is noted that the parts shown in these figures have already been described with reference to earlier figures, and that figures 42 to 46 do not add additional knowledge required for building the engine or understanding its operation.

Figures 42 to 44 illustrate second rotation elements 3 that may be viewed as having one large tooth. Figure 45 illustrates a second rotation element that may be viewed as having two large teeth. The teeth are the parts of the second rotation element that protrude into the cavity defined by the casing and the first rotation element at some part of the cycle. The teeth define a "tooth-angle", φ, measured around the axis of the rotation element 3. Typically, the second rotation element is designed so that the tooth angle is just less than 360°/t, where t is the number of teeth. In Figures 42 and 43, the tooth-angle φ is just under 360°, and the single tooth comprises three integral segments, or projecting portions. In Figure 45, the tooth-angle is just under 180°, and each tooth comprises three integral segments, or projecting portions. Figure 46 illustrates that the casing 2 may be viewed as having a slot-angle, ψ, measured around the axis of the first rotation element 3, and defined by the region where the second rotation element may project into the cavity. In the most natural embodiments of the device, the tooth-angle φ is larger than the slot angle ψ.

The above embodiments of the invention described with reference the figures are purely preferred embodiments, and are described by way of example only. It will be apparent to those skilled in the art that there are many other embodiments of the invention not described, and the scope of the invention is defined by the claims.

CLAIMS:

1. A rotary engine for use with compressible fluids, the engine comprising:
a first rotation element mounted to rotate about a first axis;
a casing having a surface enclosing at least a part of the first rotation element, an elongate cavity of varying cross sectional area being defined between a surface of the first rotation element and the casing surface; and
a plurality of second rotation elements mounted to rotate about respective different second axes, each second rotation element being mounted to project through a slot in the casing surface and to cooperate with the first rotation element surface so as to divide the cavity into adjacent working portions,
wherein each second rotation element comprises a plurality of projecting portions having respective different radii about the second axis, the different radii causing the projecting portions to project into the cavity by respective different amounts, so that the volumes of the working portions vary as the first and second rotation elements rotate,
wherein, in use, fluids in a working portion undergo compression, combustion and expansion as a closed volume, the closed volume being defined during the compression, combustion and expansion by the same two adjacent second rotation elements.

2. The engine of claim 1, wherein each projecting portion of a second rotation element spans an angle about the respective second axis, the radius of each projecting portion constantly varying about the axis.

3. The engine of claim 1, wherein each projecting portion of a second rotation element spans an angle about the respective second axis, the radii of the projecting portions stepping about the axis.

4. The engine of claim 3, wherein a number of the projecting portions of each second rotation element only partially project through a respective slot at any time during rotation of the first and second rotation elements.

5. The engine of claim 4, wherein a maximum angle spanned by a slot about a respective second axis is smaller that the angle spanned by a number of the projecting portions of each second rotation element.

6. The engine of any one of the preceding claims, wherein the first rotation element surface is a cylindrical surface.

7. The engine of claim 6, wherein the first rotation element is internal to the casing surface and the second rotation elements are external to the casing surface.

8. The engine of claim 6, wherein the first rotation element is external to the casing surface and the plurality of second rotation elements are internal to the casing surface.

9. The engine of any one of claims 1 to 5, wherein the first rotation surface is an end surface.

10. The engine of any one of the preceding claims, further comprising ignition means for ignition of a compressed fluid prior to expansion.

11. The engine of any one of the preceding claims, wherein the first rotation element further comprises at least one passage for fluid inlet and/or fluid outlet.

12. The device of any one of the preceding claims, wherein the casing further comprises a number of valves, each valve being operative as a fluid inlet or fluid outlet only when adjacent to a working portion of the cavity, and wherein each valve is only adjacent to a working portion of the cavity during a fraction of a cycle of the engine.

13. The device of claim 12, wherein, in use, each valve is never adjacent to a lowest volume working portion of the cavity during a cycle of the engine, thereby avoiding contact between valves and highest pressure fluids.

14. The engine of claim 12 or 13, wherein each of the at least one valves is operative to vary the flow rate of a fluid into a working portion of the cavity, to vary the pressure of fluid within a working portion of the cavity, or to vary a compression and/or expansion ratio of the engine.

15. The engine of any one of claims 12 to 14, wherein closed loop feedback control is used to control the operation of each of the at least one valves, the closed loop feedback control being based on at least one engine operating parameter.

16. The engine of claim 17, wherein the at least one engine operating parameter comprises at least one of fluid inlet pressure, fluid outlet pressure and rotary speed.

17. The engine of any one of the preceding claims, wherein the second rotation elements are distributed about the first rotation element, each second rotation element being mounted to rotate about a respective second axis that is perpendicular to the first axis.

18. The engine of any one of the preceding claims, wherein the first rotation element surface and the casing surface further define a seal between working portions of the cavity.

19. The engine of any one of the preceding claims, wherein, in use, an amount of projection into the cavity of each of the second rotation elements increases to a first local maximum, then decreases to a local minimum greater than zero, then increases to a second local maximum, then decreases to zero.

20. The engine of any one of the preceding claims, wherein, in use, fluids in a working portion undergo the compression, combustion and expansion within one rotation of the first rotation element.